D 35

Resourceful Decisions

Landsat in Michigan

NASA

In 1932 pioneer space scientist Robert Hutchings Goddard, whose research and theories led to the modern American space program, wrote: "No matter how much progress one makes there is always the thrill of just beginning."

Professor Goddard designed and fired the world's first liquid fuel rockets decades before men used rockets to step across earth's threshold into space. He called the task ahead "both literally and figuratively...the work of generations."

Today substantial work has been accomplished. Now earth-scanning satellites work for man in space. Called Landsats, they collect vast quantities of information about the earth to help solve natural resource management problems and answer age-old human questions.

Landsat users in Michigan are successfully applying data relayed from space to help meet resource and environmental information needs. Their experience can help others understand and apply Landsat in meeting the special challenges facing us during these final years of the twentieth century.

Contents

	Page
Introduction	1
Landsat—Voyager for Mankind	2
The Cure for "208" Headaches?	4
"Thousands of Lakes to Classify"	6
ERIM—Landsat Technical Support	8
A 300-Mile Challenge	11
Scientific Prospectors on a Worldwide Scale	12
Salvaging a Future for Wetlands, Wildlife Habitat, Recreation Areas	14
University of Michigan Remote Sensing Program	16
Consultants Specializing in Landsat	19
120,000 Square Miles for Land Cover Analysis	20
Michigan Transportation Planning	22
Michigan State University Remote Sensing Project	24
MERRA and Landsat	27
Landsat—Linking Past, Present, Future	28

Prepared Under the Direction of the
Michigan Energy and Resource Research Association
Project Director: Todd Anuskiewicz, MERRA
Writer: Roy Meador
Designers: Doug Mohl, Tom Vandegrift, Guldberg-Vandegrift Inc.
Photographer: Stanley Livingston

Cover photographs © *Stanley Livingston*

best copy available

Introduction

© Stanley Livingston

"The Only Feasible Means"

Among national priorities today, managing natural resources is a leading concern. In a 1978 national task force report to the President, Landsat is identified as cost effective for a number of applications. The report emphasizes Landsat's regular coverage, synoptic view, and the convenience of its digital format, making it possible to merge Landsat data with computerized information systems.

"For many uses, Landsat provides the only feasible means for conducting natural resource inventories," the report states. It stresses the value of Landsat to state and local governments, noting that for management of natural resources, Landsat makes "significant, often unique contributions to the information base required." The experience of Michigan Landsat users confirms task force findings.

Landsat in Michigan

When Landsat-1 was launched in 1972, a massive flood of data became available. What to do with the data was an immediate and persistent question. Some marveled at Landsat as an impressive achievement but made no attempt to use its information. Many adopted a wait-and-see attitude, intending to consider the new technology seriously when further progress had been made. A few didn't wait. Recognizing the exceptional opportunities offered by Landsat remote sensing data, and working in close cooperation with NASA, they began seeking... and finding practical applications. Prominent among those who didn't wait are Michigan scientists, government specialists, and businessmen. Seizing the opportunity and running with it, they have taken the lead in using Landsat data successfully.

Many Landsat projects in Michigan have been funded by NASA. Most have benefited from the give-and-take of harmonious collaboration among state and NASA representatives. The continuing partnership between Michigan science and NASA for practical application of Landsat remote sensing technology has been in effect several years. The results are impressive. Thanks to this joint effort, major progress has been made in translating the potential of Landsat into a working reality.

Landsat and You

On the following pages, remote sensing data users in Michigan talk about their applications of Landsat. They discuss benefits, admit drawbacks, plan for the future.

What can Landsat do for you? Perhaps little, perhaps much. The key is to begin. "Man was made to try," wrote poet Rod McKuen, "The voyager is always man, his vessel nothing less than the world." Meet those who have tried Landsat in Michigan and learned ways to make it a problem solver.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402

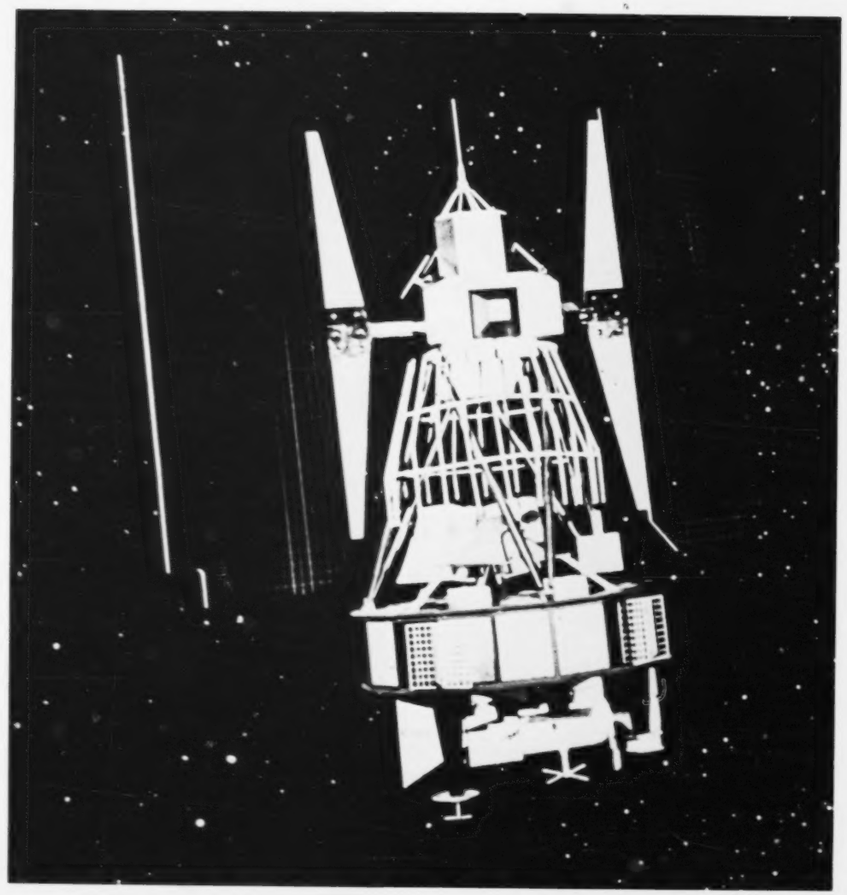
Landsat—
Voyager for Mankind

Seeing the Forest

In 1969, Homer Newell, Associate Administrator for Space Sciences and Applications at NASA, wrote, "Unmanned spacecraft lie at the heart of our total national space capability. They permit man to extend his senses into unknown and hitherto inaccessible regions." This was a good description of Landsat more than two years before the 2,100 pound satellite began performing its remarkable job.

Today from a perspective of 570 miles, Landsat orbits the earth fourteen times daily, scanning all portions of the terrestrial surface. With two Landsats operating, each point on earth is repeatedly scanned every nine days.

Synoptic views of land and water features are available from Landsat in ways never before possible. Landsat dramatically updates the ancient adage about not seeing the forest for the trees. It definitely "sees the forest," and much is learned. Landsat's altitude and its effective utilization of modern remote sensing technology make it a superior tool for environmental and resource applications. It performs jobs, at lower cost, impractical to consider by conventional means. To equal Landsat's panoramic perspective (a complete Landsat scene covers 13,225 square miles), we would have to climb a step-ladder 570 miles high. Landsat climbs for us and supplies indispensable data in formats we are just beginning to appreciate and use fully.



Applications

The special earth view provided by Landsat is increasingly valuable to earth scientists. It has been used to reveal geologic faults, prospect for uranium, oil, copper, water. It has assisted in making and correcting maps, detecting oil slicks at sea, even locating shrimp fishing grounds. The scope and variety of Landsat applications in natural resource study, inventory, and management are steadily expanding.

Landsat is being used to advantage right now in these vital areas of need:

- **agriculture, forestry, and range resources**
- **land use and mapping**
- **geology**
- **water resources**
- **oceanography and marine resources**
- **environmental monitoring**

Landsat Offers Users These Continuing Advantages

REPETITIVE COVERAGE: Surface conditions are regularly monitored on a precise schedule.

MANY FORMATS: For user convenience, Landsat data can be acquired in a wide range of formats including computer compatible tapes, false color composites, imagery (color or black and white), and Landsat mosaics.

COST EFFECTIVENESS: The cost effectiveness of Landsat for many important applications is convincingly established.

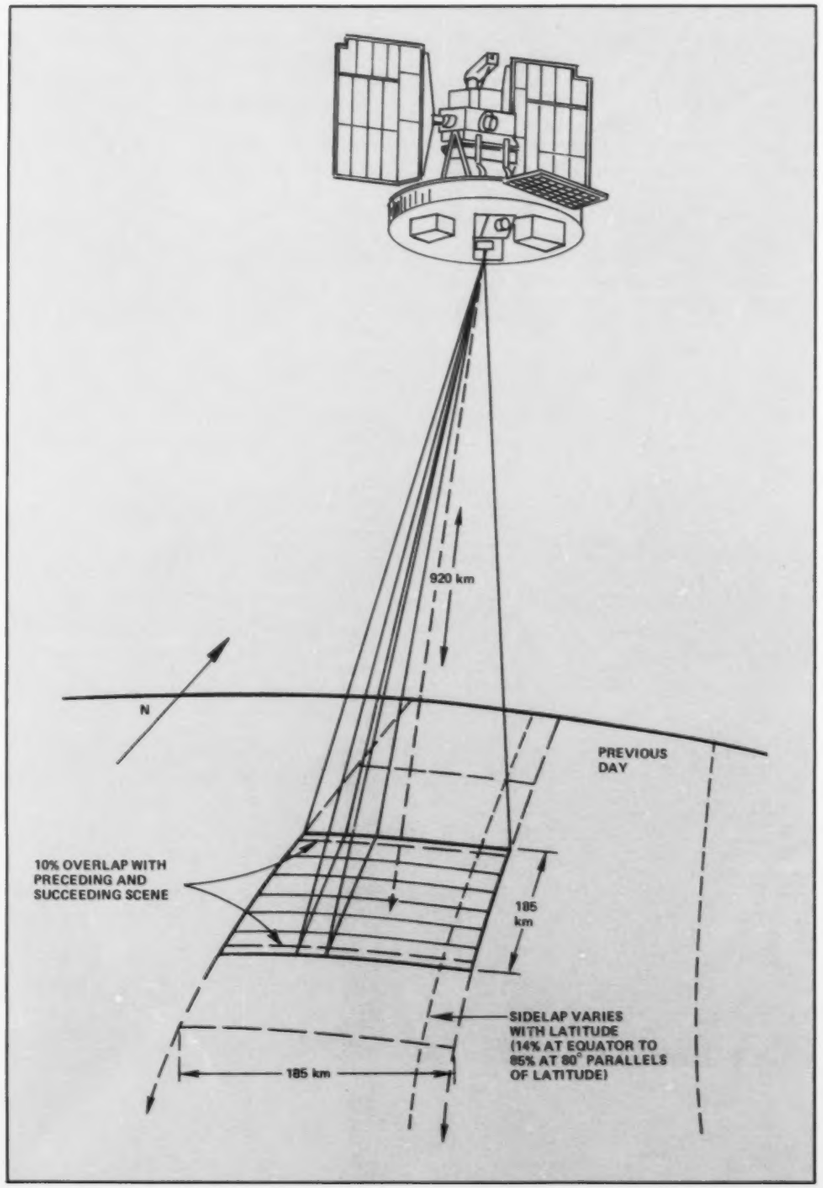
Remote Sensing Data Collection Aboard Landsat

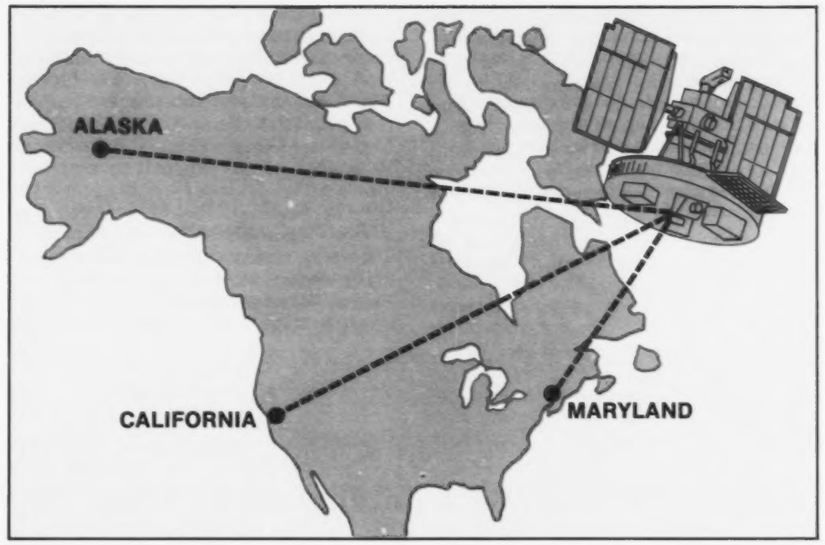
Multispectral Scanner (MSS): This is the chief remote sensing device aboard Landsat, and remarkable is an appropriate word for it. The MSS has four bands sensitive to electromagnetic radiation. These bands take advantage of the fact that various materials reflect light at different wavelengths. Vegetation, for instance, reflects more green and infrared than red light. Each MSS band provides information inaccessible to the other bands, as the "spectral signatures" of different materials are recorded by Landsat. In addition to scanning, the MSS collects and converts data to a digital form for transmission to earth.

The MSS has a "Made in Michigan" label as part of its history. Much of the original research, design, and production work on the MSS was accomplished for NASA at the Environmental Research Institute of Michigan and the Bendix Aerospace Systems Division in Michigan.

Return Beam Vidicon (RBV) Camera: Video pictures, supplementing MSS imagery, are taken by the Return Beam Vidicon Camera aboard Landsat.

READEX FICHE


920 km
N
PREVIOUS DAY
10% OVERLAP WITH PRECEDING AND SUCCEEDING SCENE
185 km
SIDELAP VARIES WITH LATITUDE (14% AT EQUATOR TO 85% AT 80° PARALLELS OF LATITUDE)
185 km



How Landsat Collects and Delivers Earth Data

A. Collecting and Converting: The MSS scans west to east on a 115 mile path in 33.0 milliseconds and digitizes four different wavelengths of earth radiation.

B. Data to Earth: NASA receiving stations at Fairbanks, Alaska, Goldstone, California, and Greenbelt, Maryland (as well as those now being authorized in other countries) copy streams of numbers sent by the satellite. When beyond receiving station range, Landsat stores data for later delivery.

C. Processing Numbers: Tapes from the receiving stations are processed into black and white images and computer compatible tapes (CCT's) at NASA Goddard Space Flight Center. Color images can be created from black and white versions of the four MSS bands using color filters. The resulting "false color image" is the familiar, widely published Landsat color product.

D. Products: After processing, films and CCT's are available in quantity and variety from the EROS Data Center, Department of the Interior, Sioux Falls, South Dakota.

E. Interpretation: With practical use of Landsat data as the endpoint, accurate interpretation is indispensable. When relating known earth data to corresponding Landsat data, scientists apply "Ground Truth" (collected from field observations, photography, and other sources). Computers classify Landsat "pixels" (1.1 acre minimum areas) in accordance with ground truth. Interpretation follows through visual inspection of images or analysis of digital data, and often both.

Michigan GLS Region V Land Use Determinations

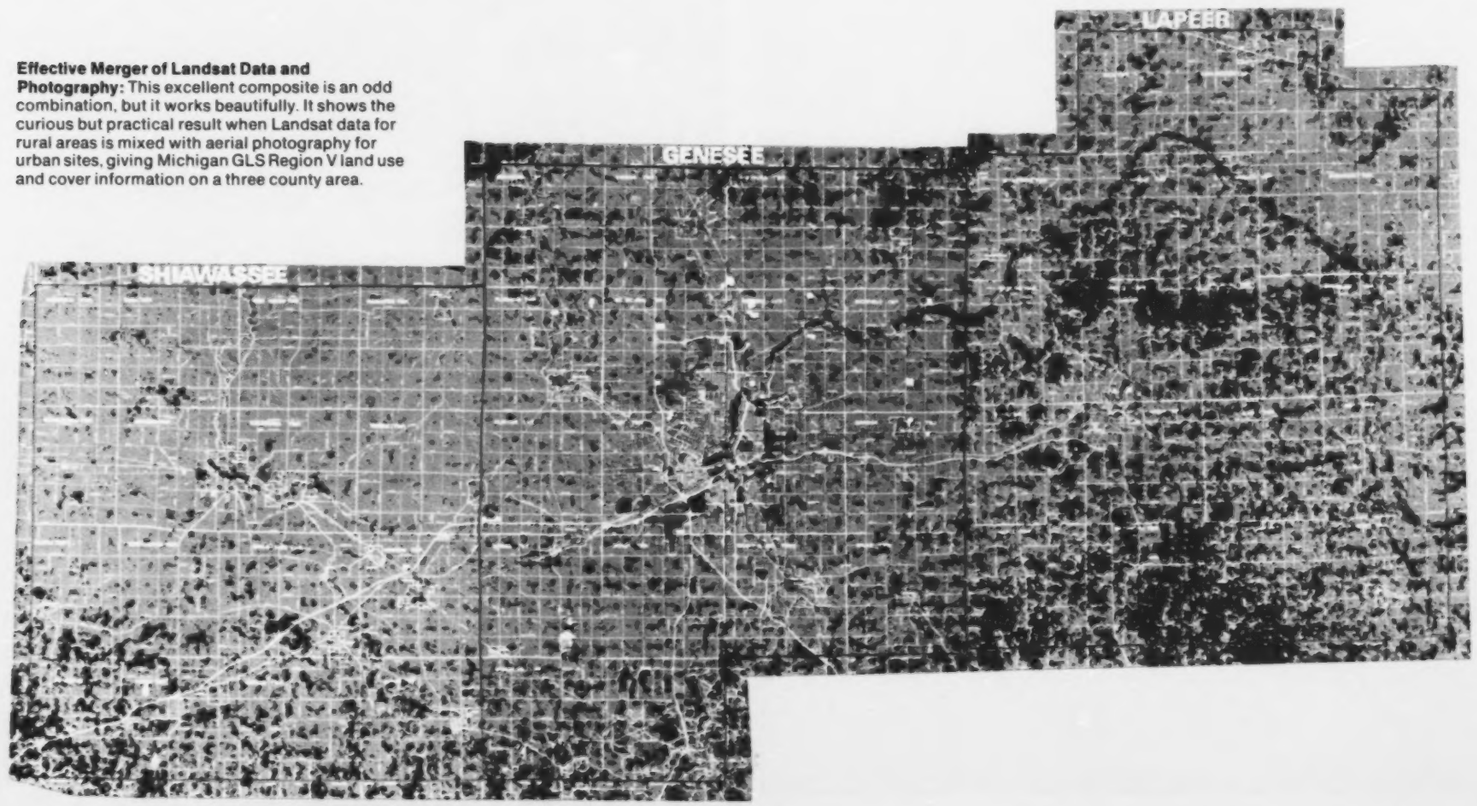
Is Landsat the Cure for "208" Headaches?

For a growing number of states, "208" and "Landsat" are synonymous. Michigan can be included. Preparation of "208 Reports" in compliance with Section 208 of Public Law 92-500 is a nationwide undertaking aimed at establishing an accurate environmental record of current land use and regional water quality together with practical planning for effective waste treatment management.

Remote sensing with heavy reliance on Landsat imagery has proved a time and cost saver in the land use aspects of this work. "In Michigan's Region V we faced a deadline, and Landsat data saved us," reported Bob Karwowski, 208 Project Manager in Genesee-Lapeer-Shiawassee Region V.

Classic Example of Three-Way Scientific Cooperation

The map below, an important Landsat first showing land use cover in GLS Region V, combines Landsat data for rural areas with aerial photography in urban locations. The result is a helpful composite accomplished through the collaboration and combined skills of three organizations. The idea of merging Landsat data with photographic data came from Steve Tilmann at Michigan State University's Remote Sensing Project. Twelve categories of land cover were identified. Imagery from a Landsat flyover in August 1975 was used for agriculture and open space, forestlands, wetlands, and open water categories. The other eight urban categories were determined from aerial photographs at the MSU Remote Sensing Project. The Bendix Aerospace Systems Division merged the two sources, producing magnetic tapes and the following land use/cover map for the region. MSU prepared land use maps for each county from the computer tapes. According to Bob Karwowski, "At Region V, we use the computer data and county overlays regularly. Computerizing this information is a key development."



Effective Merger of Landsat Data and Photography: This excellent composite is an odd combination, but it works beautifully. It shows the curious but practical result when Landsat data for rural areas is mixed with aerial photography for urban sites, giving Michigan GLS Region V land use and cover information on a three county area.

"Future planning makes little sense until existing land use is known. That's why Landsat is such a boon to planners and one of the nicest ideas to come along. Landsat data can give us almost a motion picture of growth through periodical repeat coverage. It would be great to have this information updated every three to five years. Think if we had such data since 1940? Or what it will mean in 2000 to have it from now on? The potential of such continuing data accessible on computer tape is phenomenal. There are many different ways to massage the figures for all sorts of useful answers."

Robert Karwowski
208 Project Manager
Michigan GLS Region V Planning and Development Commission
1602 West Third Avenue
Flint, Michigan 48502
313-766-8593

Time Short, Send for Landsat

Even when time isn't short and funds scarce, if that ever happens, the evidence is that Landsat is still the right choice for much 208 work. When the GLS Region V project started, Tom Haga, then Executive Director of the Planning Commission, worked with Landsat and found it a convincing asset in land use studies. "For regional or larger areas it is more economical than traditional methods," notes Mr. Haga. Now a Flushing, Michigan consultant (at 313-659-3809), Tom Haga expects to make use of Landsat extensively in the future.

Bob Karwowski admits that his appetite for more Landsat data has been whetted. He hopes present and future Landsat developments will solve previous drawbacks—problems distinguishing cultivated from uncultivated land, or wetlands from open space or forests. Despite some drawbacks, present Landsat data are welcome and useful. "Give us regular access to a computer terminal. Let us feed in what we already know, and the capacity for development is limitless as we massage and apply the data we have. The possibilities excite us," contends Bob Karwowski.

"Thousands of Lakes to Classify"

An Opportunity for Landsat at DNR

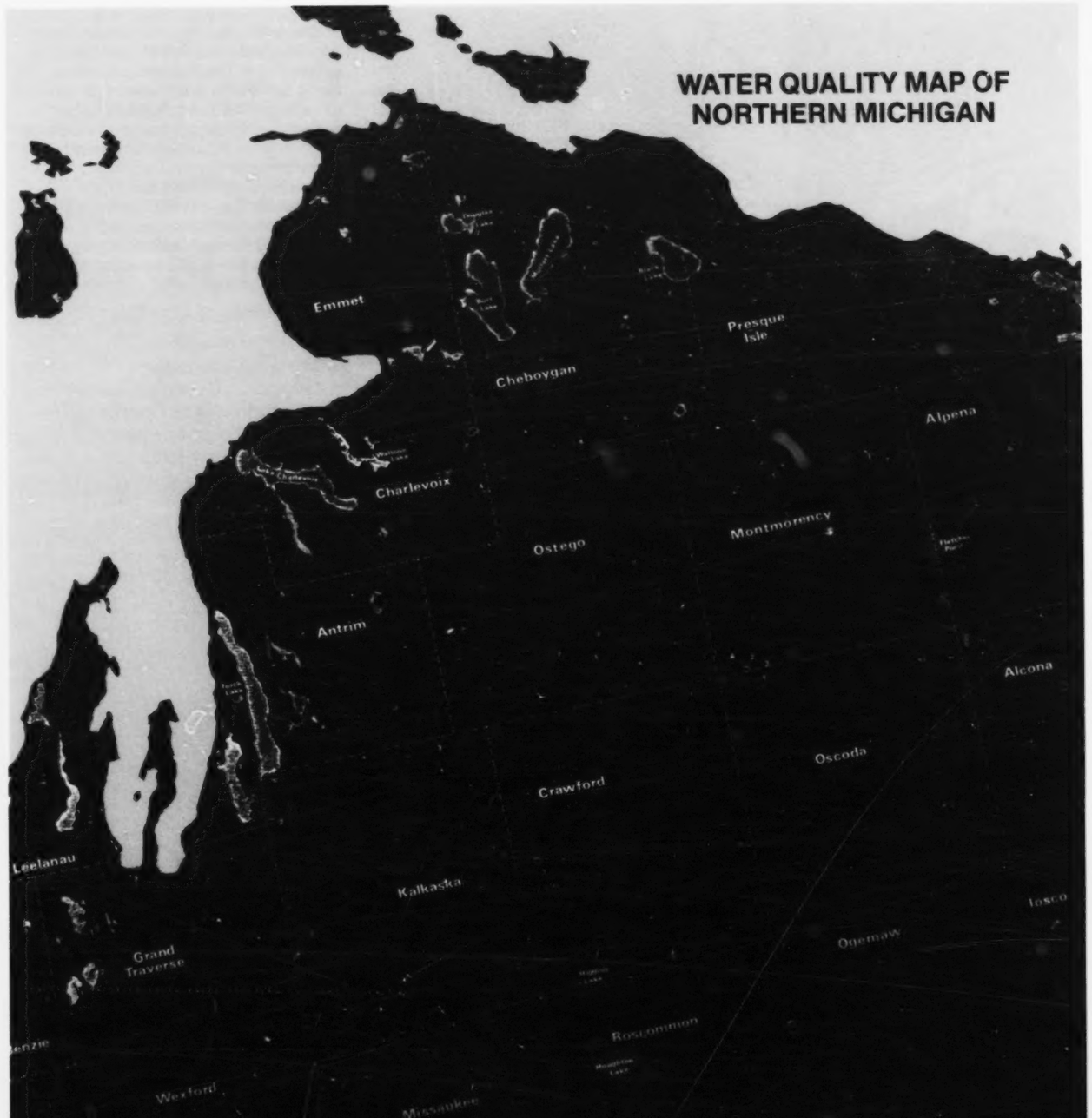
Michigan's 10,000 lakes provide Landsat with another application that has proven a natural for satellite imagery. Recognizing the national importance of lake resources, states now, under Section 314 of Public Law 92-500 Water Pollution Control Act, must classify lakes for their trophic status and develop appropriate management programs to prevent their degradation.

"No Other Reasonable Alternative"

Classifying lakes, especially for a lake-rich state such as Michigan, is easier to legislate than accomplish. That's why people at Michigan's Department of Natural Resources (DNR) and their counterparts in other states welcome Landsat as a feasible answer to a mammoth challenge.

Studies have indicated the technical and cost effectiveness of Landsat for monitoring the trophic conditions of lakes. Dr. Bob Rogers, now with the Environmental Research Institute of Michigan, in a 1977 report on eutrophication in the Great Lakes Basin said of Landsat that "there is no other reasonable alternative for accomplishing this task." In neighboring Wisconsin, Landsat is the basis of a tentatively accepted lake classification procedure.

With optimum resolution down to 80 meters squared, Landsat is suitable now for monitoring lakes 50 acres or larger (Michigan has 2,000). The capacity of Landsat for follow-up monitoring is a further advantage hailed by lake management scientists such as Richard Mikula at DNR. His goal is to use Landsat for lake classification during periods of summer growth, then to repeat the monitoring process at periodic intervals.



Classifying lakes is a practical, long-range application of Landsat especially important in Michigan, a state of many lakes. This Water Quality Map of Northern Michigan represents progress toward that goal. Prepared by Bendix in the course of a NASA-sponsored lake eutrophication survey, the map shows Michigan lakes ordered by level of enrichment/eutrophication based on total biomass. It indicates what has been and can be done to perform useful, economical water quality studies with present Landsat facilities.

Larry Folks and Richard Mikula of Michigan DNR discuss the use of Landsat to survey Michigan lakes of 50 acres or larger in a future project.

"I don't believe it's a secret any longer that lakes are critical components in the environment and highly sensitive natural resources. With 2,000 lakes to classify in Michigan for transparency, chlorophyll in water, and total phosphorus levels, the conventional lake sampling method is too slow and costly. In four years we managed to sample only 300 lakes. Our Self-Help Program, with citizens submitting lake samples, covers about 150 lakes per year. Useful as they are, such programs fall far short of the total and far short of what is needed, both legally and practically, in this state. Landsat has the potential for giving us the means of monitoring these lakes during a single summer growth period, and following up periodically."

Richard Mikula
Inland Lakes Management Unit
Division of
Land Resource Programs
Michigan Department of
Natural Resources
Box 30028
Stevens T. Mason Building
Lansing, Michigan 48909
517-373-8000

◆ Sherman Hollander, in the Program Development and Services Section of DNR, prepares an overlay map of Michigan, dividing the state into nine square mile quadrants. The map, used initially for aerial photography surveys, will subsequently be used in establishing ground truth for Landsat imagery acquired to study and classify the trophic condition of Michigan lakes.

ERIM Applications Division

Source for Landsat Technical Backup from Michigan to Ouagadougou, Africa

25 Years of Leadership in Remote Sensing Technology

At Ouagadougou in Central Africa, ERIM scientists helped establish a Landsat receiving and processing station. This effort is one from a long list of accomplishments in remote sensing by the Environmental Research Institute of Michigan (ERIM) since 1953. ERIM scientists contributed essential refinements to the multispectral scanner used aboard Landsat. High resolution radars, laser-scanners, and advanced processing systems are among other important results from ERIM technology research. ERIM has participated in all phases of Landsat programs, from advanced design to hardware, software, and applications.

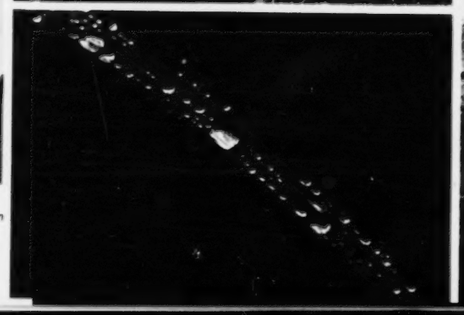
ERIM is a not-for-profit corporation established in 1972 as a research center succeeding the Willow Run Laboratories of the University of Michigan. ERIM supplies professional skill to solve problems in modern sensor technology and other technical fields for sponsors and clients in government, universities, and business. Its role in development and application of Landsat technology is international in scope.

ERIM has been involved with Landsat development from the start, in engineering and research as well as finding new uses for Landsat products. Applications are such a paramount concern that an Applications Division under ERIM Vice-President Don Lowe was started in 1978, with the responsibility of developing remote sensing programs for clients around the world. Anyone entering the ERIM lobby on Plymouth Road in Ann Arbor is impressed by the display of remote sensing imagery—including Landsat—representing ERIM projects for many countries and continents.

A Scientific Merger Foretells Future Landsat Progress

Baseball fans might consider it equivalent to Detroit Tigers and New York Yankees uniting to form the Detroit Yankees. In May 1978, ERIM's remote sensing leadership role was substantially enhanced when the Bendix Earth Resources Data Center (ERDC), equipment and personnel, joined ERIM in a gift-purchase arrangement. ERDC, under manager Charles L. Wilson, is part of ERIM's Applications Division. This now gives ERIM what is considered the largest nongovernment processing facility in the world.

ERIM since 1962 has sponsored international Symposia on Remote Sensing of Environment. It follows up research with technical support, seminars, and expert guidance. ERIM scientists are effective spokesmen for remote sensing and Landsat. Dr. George Zissis, testifying before Congress, stressed the need for an "operational Landsat-type system...to play a vital part in meeting today's needs for earth resources information." Today's needs and tomorrow's are certain to see ERIM as well as Landsat playing a vital part.



© Stanley Livingston

Dr. Rogers with 10,000 square miles in hand. Each Landsat tape in this ERIM file holds data for up to 10,000 square miles (530 tapes cover the United States).

"Landsat is equipped to do many things well right now. Lake surveillance is an example. We sample a few lakes for ground truth, then Landsat lets us cover hundreds of lakes. We can use Landsat on a continuing basis to monitor lakes, water quality, wetlands, and other aspects of environmental concern. Why delay until the wheel squeaks? Too many are waiting for others to act first, or for satellite data to be pronounced 'perfect.' The quickest way to get ahead with new technology is to use it actively and learn from applications how to make it better. Our job is to show non-technical citizens, including public officials and decisionmakers, that remote sensing products are useful, simple, and economical. Our Applications Division exists to open doors for this technology, and put to rest the cliché that Landsat is still a solution looking for problems. The problems are there. The solution is available. We're trying to bring them together."

Robert H. Rogers, Ph.D.
Applications Specialist
ERIM Applications Division
P.O. Box 8618
Ann Arbor, Michigan 48107
313-994-1200

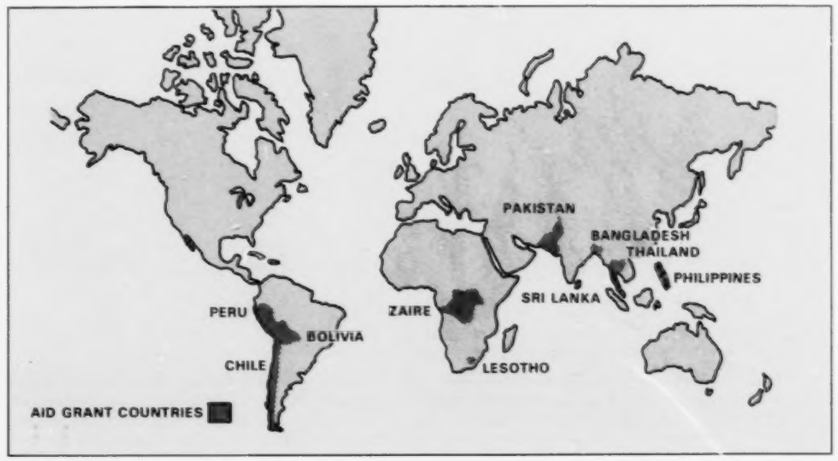
Bob Rogers has been involved in many of Michigan's most successful Landsat applications—the Michigan Region V project, lake eutrophication in the Great Lakes Basin, water quality and land use studies. Dr. Rogers emphasizes the repeat monitoring ability of Landsat and regrets it is underused. His views are echoed at ERIM by Fred Thomson, heading the Resources and Technology group. Mr. Thomson considers Landsat "Essential for large area views." His response to the indifference sometimes encountered in the user community is to "show them how it can help them do their jobs, teach them it is a useful tool."

Scientists with Worldwide Destinations

Landsat helps keep modern scientists on the move, especially applications specialists from ERIM. During 1978 many ERIM scientists typically were on assignments in far places. Ground truth experts John McKeon, Ray Laurin, and Frank Okoye gathered field data in the rugged, little-explored Andes of southwestern Venezuela. Their information will be used in computer-assisted categorization of Landsat data needed to prepare land cover maps and make management recommendations on resources to the Venezuelan Ministry of Energy and Mines.

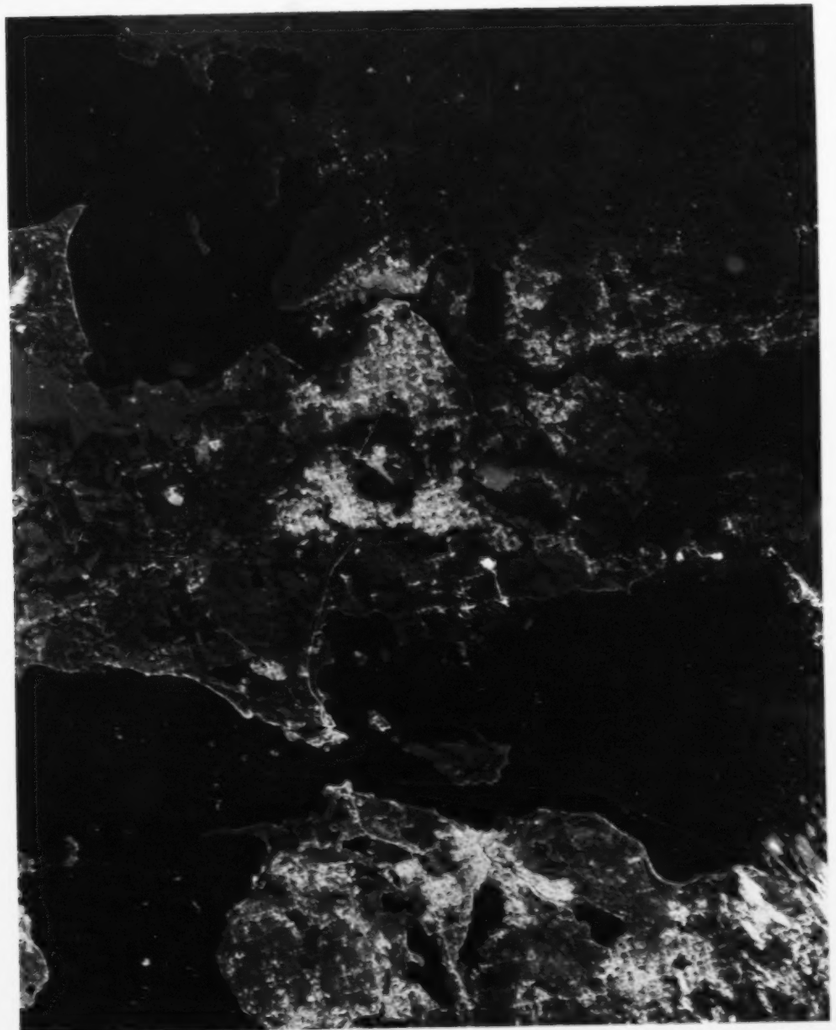
At Telespazio in Rome, Italy, Landsat authority Albert Sellman was on assignment for a year helping European scientists establish a Landsat applications program. ERIM scientists Fred Thomson and Frank Sadowski conducted a Remote Sensing Seminar in Lima, Peru as part of ERIM's collaboration with the U.S Agency for International Development to demonstrate the use of modern sensor data (especially Landsat data) in developing countries. AID grants, administered by ERIM, have gone to ten countries selected on a competitive basis (see map for locations). Thomson and Sadowski were active in the Peruvian project. Peruvian scientists are being assisted in determining the utility of Landsat for mapping Aguaje palm and other forest associations in the jungle areas of the Amazon Region. Much of this remote area has never before been surveyed.

These and other ERIM travelling scientists are carrying the technological word and know-how to many regions where Landsat and remote sensing methods can prove major boons for economic development.



ERIM Offers Expertise for New Technology

Meet Three Experts in Landsat Processing and Applications



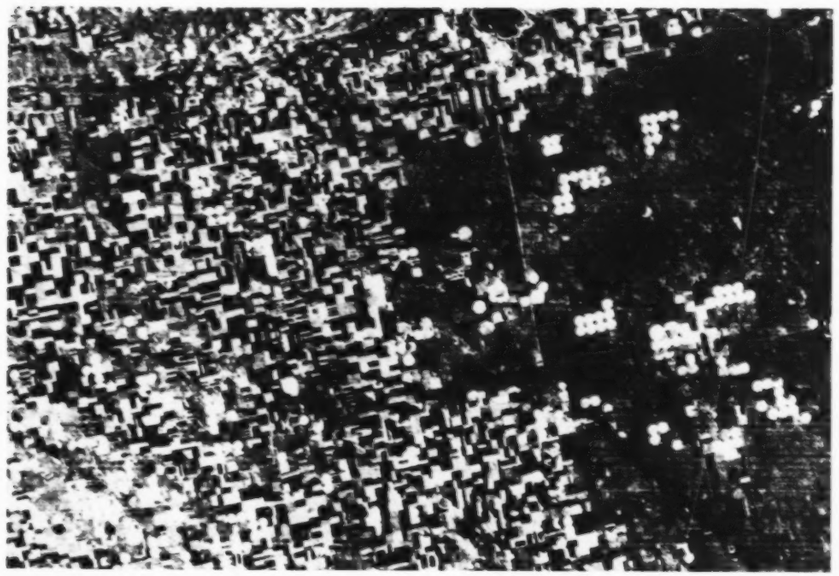
Processing and interpreting Landsat imagery is a specialty of the Environmental Research Institute of Michigan. ERIM has the equipment and the experts to utilize Landsat information fully. This Landsat image of Upper Michigan means little to the casual observer. At ERIM, studied by specialists, it can help answer important environmental and land use questions.

Head of ERDC
Charles L. Wilson, Manager of the Earth Resources Data Center at ERIM, has been active in remote sensing almost two decades. Among many key Landsat projects in which he has participated—and earned a place in the history of this technology—was his direction of multispectral scanner development during the 1960's.

"The Idea Man"
Robert H. Dye, Senior Research Engineer under Director Don Lowe in the Applications Division, is one of the scientists here who feels professionally at home among wall to wall computers. When Landsat images are produced at ERIM and elsewhere, they are often products of the computer hardware and software designed by Bob Dye.

"Image Interpreter"
Larry Reed is an ERIM Research Associate who "keeps the computers running." He is a certified photogrammetrist, but with his work now expanded far beyond photography, he considers "image interpreter" more accurate today. Larry Reed is shown at the interactive display with a Landsat image on the screen. He was involved with this equipment in the Michigan Region V composite map project, and calls it "still one of the best efforts to date using Landsat data."

Commonwealth Associates Copes With a 300 Mile Challenge

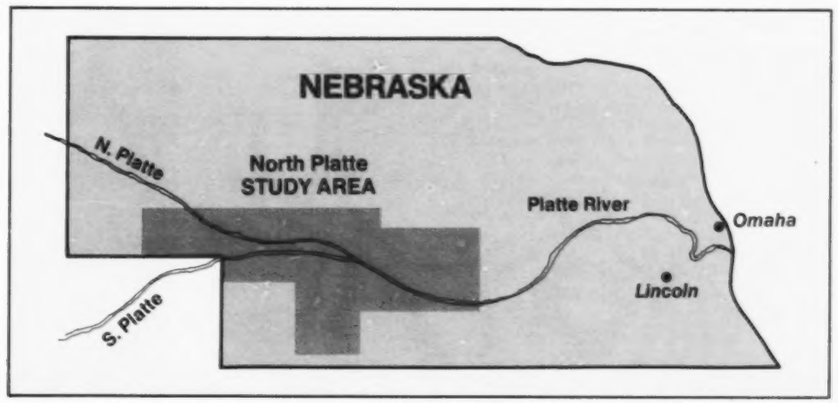


Commonwealth Associates Inc., consulting engineers in Jackson, Michigan, had a tough one: Routing a 300 mile power line in Nebraska and only a few weeks to produce a land use constraint map of the area. The assignment fell to Sherman Hollander. He wondered if perhaps Landsat could help "narrow down the corridors?" His associate on the power line routing assignment, Mike Barningham, Project Manager for environmental studies, agreed he should go ahead.

"With approximately 9,000 square miles to cover, we had to accomplish what amounted to a Level One Land Use Classification. Landsat images fortunately were available from the University of Nebraska, saving us time. We used eight scenes, and concentrated primarily on a late July-August sequence. The latter was a great help in determining irrigated areas, especially pivot irrigation systems. Farmland types were a critical consideration in our routing analysis. Landsat served impressively to identify irrigation areas, farmlands, wetlands, etc. One main advantage of Landsat for this project was the comprehensiveness. It provided a single-source land use data base. Existing land use maps in the study area were piecemeal and spanned a time period of ten years. Landsat gave us up-to-date information. Working at the Commonwealth offices in Jackson and using largely manual interpretation, we finished on time. We were able to complete the entire interpretation and mapping process in six weeks totally from Landsat."

Sherman Hollander
Division of Land Resource Programs
Michigan Department of Natural Resources
P.O. Box 30028
Stevens T. Mason Building
Lansing, Michigan 48909
517-373-3328

Sherm Hollander joined the Michigan Department of Natural Resources after completing his Landsat mapping project for Commonwealth Associates. He will do further work at DNR meshing Landsat with the state's newly acquired color-infrared photography. Mr. Hollander welcomes questions about his successful effort to meet that sticky 300 mile deadline in Nebraska using Landsat.



Landsat band five did the job for Commonwealth Associates in Nebraska's range and farm country when a land use constraint map was needed in a hurry for a 300 mile power line routing project. This was one of the band five images used to identify irrigation systems, farmlands, and other critical land use determinations.

GeoSpectra Corporation

Specialists in Geological Applications of Landsat

Scientific Prospectors
Locating Oil, Gas, Uranium, Minerals, and Water Worldwide

The popular idea of a prospector is an oldtimer with a mule hunting paydirt in them thar hills. Today Landsat and modern technology supply hard-to-beat competition. At GeoSpectra in Ann Arbor, scientists use Landsat tapes, Topoimages™, gray maps, and other remote sensing tools to study faults, surface color, and related earth signals in locating minerals and valuable resources. "Prospecting," as the oldtimer might say, "sure ain't what it used to be."

Bob Vincent, Ph.D. geologist and GeoSpectra President, is a strong believer in the free enterprise possibilities of Landsat. He founded GeoSpectra in 1974 to take advantage of the new technology and to assure clients fast response. "For quick action, come to a small, technology oriented company," suggests Dr. Vincent, "We work at eliminating inertia and bureaucracy."

GeoSpectra purchases computer compatible Landsat tapes and processes them to enhance features of special interest to clients. The firm's unique software program, responsible for the excellent Landsat images it supplies as products, was developed by Vice President Ronald Harrow. GeoSpectra supplies and interprets high quality Landsat images, while providing a wide range of remote sensing services.

Dowsing Rod 570 Miles High

When GeoSpectra searches for oil, gas, uranium, copper, etc., it primarily relies on Landsat data. GeoSpectra scientists have mapped the coastal zone of South Carolina and oil slicks off the coast of Europe. For the state government of Tamil Nadu in India, GeoSpectra helped locate faults indicative of water reservoirs, and wells are now being drilled. In Michigan an oil company is drilling an exploratory well at a site selected by GeoSpectra using Landsat.

Hunting Oil in Michigan: Above is a Topoimage of the Grand Traverse area in Northern Michigan. The Topoimage is a GeoSpectra innovation based on topographic data. On the right is a Landsat image (prepared by ERIM) of the same area. GeoSpectra uses such images together with computer tapes and gray maps to study geologic features. This approach located faults, confirmed by seismic data, elsewhere in Michigan. An exploratory oil well is being drilled. According to Dr. Vincent the combination of Landsat and Topoimages is providing vital new information on structural features in Michigan and elsewhere.

"There's no doubt Landsat is the best wide-area reconnaissance tool available for mineral and hydrocarbon exploration. It works great in identifying locations where seismic surveys should follow. The cost saving with Landsat is tremendous. With Landsat data, we can remain in Ann Arbor and visit any place on earth. It could make Ann Arbor the exploration capital of the world. Landsat is a major leap forward in studying and understanding this planet. The right way to explore for resources today is to use satellite data first before more expensive methods. This applies to oil, gas, and minerals. Landsat is so cheap compared to the competition, you can't afford not to use it."

Dr. Robert K. Vincent
President
GeoSpectra Corporation
Consulting/Data Processing/
Image Interpretation
320 North Main, Suite 301
Ann Arbor, Michigan 48104
313-994-3450

Being small and specialized is considered an advantage by the Landsat experts at GeoSpectra. New ideas are part of the atmosphere, and staying two steps ahead of the competition in the application of Landsat technology is a welcome challenge to GeoSpectra scientists. Innovation (as in the case of Topoimages) has more than a fighting chance here, it has a standing invitation. GeoSpectra is a place where, in Dr. Vincent's words, "scientists get their hands on the data." They process it themselves, then deliver Landsat information, refined and interpreted, to help solve tough problems and support difficult decisions. To learn more about GeoSpectra's special use of Landsat data, get in touch.

Dr. Vincent studies a Landsat image to "find faults" in Venezuela. Many of the remote, inland areas may never previously have been explored. But Landsat covers almost every point on earth, allowing the modern scientist-explorer to stay home and make important discoveries.

Computer scientist Ronald Harrow obtains raw Landsat data, massages it at the University of Michigan computer center, and then receives Landsat information as required at GeoSpectra's remote terminal.

Salvaging a Future for Wetlands—Wildlife Habitat—Recreation Areas

Swamps and Bogs No Longer

Once dismissed as wastelands until drained and cleared, they are now respectable as "wetlands." Yet despite increasing awareness of their importance—for groundwater filtration, water quality regulation, recreation sites, and waterfowl and wildlife habitat—wetlands continue to be lost at an alarming rate. A Michigan DNR report indicates that between 50 and 77 per cent of Michigan's wetlands were destroyed during the past century.

Today Michigan and other states are committed to the protection of wetlands from further degradation and have a clear mandate to inventory wetlands and devise effective management programs. With wetlands dwindling rapidly, an accurate, up-to-date wetland information data base has become essential for effective resource management and decision making.

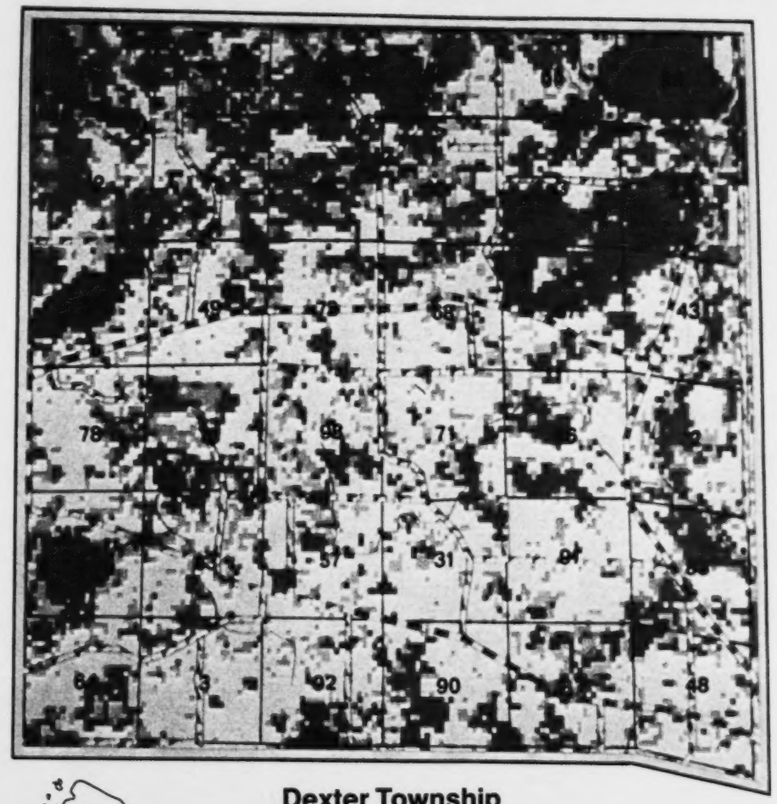
Assignment for Landsat

Remote sensing techniques such as aerial photography and Landsat provide an effective way to acquire some of the environmental information needed for an accurate data base. In a 1977 report on a wetlands inventory study sponsored by NASA, "Remote Sensing of Wetlands," Norman E.G. Roller, an ecologist and remote sensing specialist with ERIM, gave numerous examples of the effectiveness of remote sensing in various wetland inventory applications. Recognizing the superiority of aerial photography for some applications, he noted that "for extensive, general purpose wetlands inventories ...the use of Landsat data may be more cost-effective."

With many areas serving simultaneously as wetlands, wildlife habitats, and recreation sites, a triple motive for protection and preservation is given. Large marshlands can offer a home for fish, water fowl, and furbearers, as well as a refuge for countless citizens to hunt, fish, photograph nature, or just enjoy the out-of-doors. How to preserve such areas for the future? The first step is the familiar one: Classification, inventory, assessment. In this work where the need is immediate and budgets limited, remote sensing, including Landsat, is a useful option.

© Stanley Livingston

HABITAT QUALITY RATINGS FOR WHITETAIL DEER



Dexter Township
Washtenaw County, Michigan

Scale 1 Mile

Southern Michigan Wildlife Habitat Evaluation Model: "Landsat allowed us to take a detailed look at habitat quality in a time frame and for a lower cost than ever before available," said Norm Roller of this map. He noted that excessive time had to be spent confirming mapping accuracy in this pilot study, but "in future programs we'll be able to trust the technology and emphasize biology rather than mapping." The map identifies, by objective ratings, areas of high quality to be protected as well as poorer areas in need of upgrading. "The ratings are from a computer model which uses digital cover type maps produced by Landsat or other sources as input," explained Norm Roller. Habitat models, such as the above, are valuable to managers, planners, and lovers of the wild.

"Isn't it axiomatic that if we don't save the wilderness we have, we soon may have none? The ecological warning implicit in the philosophy of wilderness and wildlife habitat preservation is that if we fail to preserve habitats for other species, we endanger our own. By helping deer, birds, or other animals, we help ourselves. In this matter, fortunately, we're no longer static. Landsat gets credit for giving us a start toward effective wetland and wildlife management. Why? Landsat stimulated the digital data base approach which is the key. Even on studies where Landsat is not currently required because other data gathering methods are being used, five years from now Landsat may be essential because new aerial photography or ground data aren't available or are too costly. Landsat's capability for periodical updating and the fact it gives us a look at the total resource picture are irresistible arguments in its favor. Thus, Landsat in many applications, including wetland monitoring and wildlife habitat studies, can fill a critical information gap. This information is vitally needed to help formulate far-reaching policies determining the future of these important resources."

Norman E. G. Roller
Earth Resources Remote Sensing Applications
Environmental Research Institute of Michigan
Post Office Box 8618
Ann Arbor, Michigan 48107
313-994-1200

Secondary Models—Another Dividend

The habitat evaluation model and digital data base approach, inspired and made feasible by Landsat, confers other benefits, in addition to its main purpose. This same remote sensing data base can be used in secondary computer models—to generate information and supply guidance on the best routes for various recreational and other activities.

The frequent use of Landsat with these models can be expected because of cost advantages, versatility, and the practicality of easy updating, according to Norm Roller. He thinks new satellites with more channels and finer resolution will increasingly supplement and possibly even supplant traditional remote sensing and field methods. In some applications— monitoring certain water quality parameters is an instance —Landsat has already proved its superiority for large area surveys of changing conditions.

© Stanley Livingston

University of Michigan Remote Sensing Program

Applying Landsat and Other Remote Sensing Technologies to State and World Problems

Calling on the School of Natural Resources Remote Sensing Program at the University of Michigan, you quickly realize this is no ivory tower haven for theoreticians. Highly practical remote sensing applications work is conspicuously underway as Masters and Ph.D. candidates wrestle with real problems involving every aspect of the environment and resource management.

Multiple Disciplines, Varied Skills

In a well-equipped laboratory, students, research assistants, and professors work together seeking answers to earth puzzles utilizing remote sensing tools. The current program, in progress over a decade, leads to the Master of Science Degree in Remote Sensing. Several university departments participate, including the Departments of Geography, Geology, Mineralogy, Civil Engineering, Electrical and Computer Engineering.

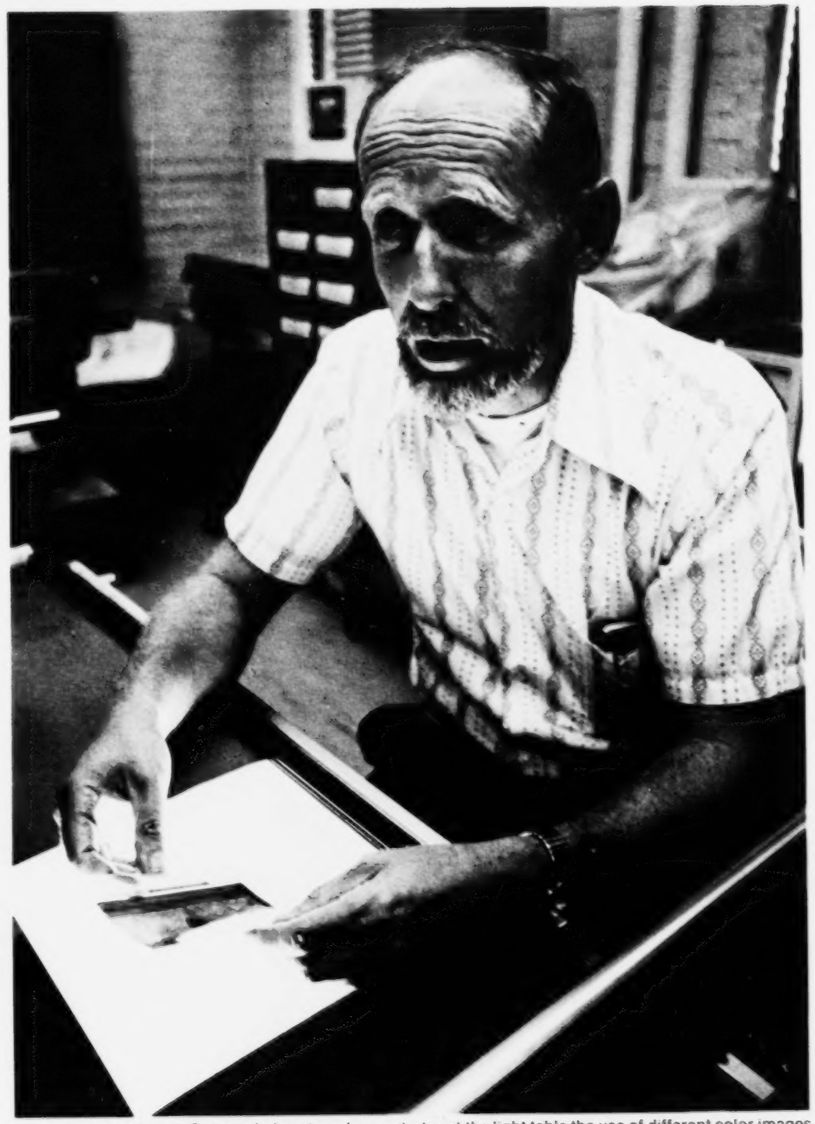
At the University of Michigan, remote sensing is aerial photography... Landsat ...radar...infrared...photogrammetry ...computer processing. It's the whole complex of technologies and skills available today to the remote sensing specialist. The University of Michigan has been in the forefront of major universities training remote sensing professionals for the expanding needs of business, government, and research. Graduates of this program are found in key positions at government, university, and private industry centers where remote sensing has become an important information source.

In the University of Michigan Remote Sensing Program Laboratory, students and teachers jointly solve earth problems and meet contemporary challenges using Landsat and other modern remote sensing methods.

"We've proved Landsat data can be useful without dependence on elaborate and expensive computers. Experienced human interpreters working directly with computer enhanced imagery to complement computer interpretation can produce accurate results at a lower cost. Landsat must be adapted to simple computer applications to realize its full potential in less developed areas of the world, and even here where limited funds are available to acquire data and process it. A better balance between man and machine is one of our goals. Another is to get the job done now instead of waiting until next year."

Dr. Charles E. Olson, Jr.
Chairman,
Remote Sensing Program
The University of Michigan
Samuel Trask Dana Building
Ann Arbor, Michigan 48109
313-764-1413

The spectral radiometer is a good friend of Landsat on the ground. Dr. Olson shows how it is operated to measure reflectance based on the intensity of sunlight. This instrument together with others, such as a thermal radiometer for temperature readings, are carefully used in the field to compile readings that will serve as indispensable ground truth for Landsat data.



Dr. Olson in the Remote Sensing Laboratory demonstrates at the light table the use of different color images to make an inexpensive, but quite good color composite. This do-it-themselves approach is a commitment at the laboratory that helps reduce expense and gets jobs done faster.

Dr. Olson has been Chairman of the Remote Sensing Program since 1972. "Less aesthetics, more human interpretation" summarizes his approach to the use of Landsat. He believes good information on vegetation and other matters is available directly from computer tapes using ordinary business computers when image interpreters do more of the work. Training expert image interpreters is one of Dr. Olson's long-time specialties.

What Do You Need to Know About Remote Sensing?

Remote sensing consultation and guidance is an important part of the University of Michigan's continuing program. Trained students are available as interns. They get valuable experience, clients get useful work at economical rates. To help meet needs in Michigan for remote sensing information and instruction, Dr. Olson also arranges for speakers, seminars, and training programs. In June 1978, for example, a highly successful Vegetation Remote Sensing Workshop was held in northern Michigan. Participants learned how to apply Landsat and aircraft imagery in vegetation surveys.

Dealing with practical problems is the heart of the remote sensing program at the University of Michigan. Students master techniques by applying them early to actual, real-world problems. Even as they learn, they make important contributions, working side by side with their instructors.

Skills in the interpretation and use of Landsat data are found elsewhere in Michigan, but nowhere more readily and practically than in the combined education-applications program for remote sensing at the University of Michigan.

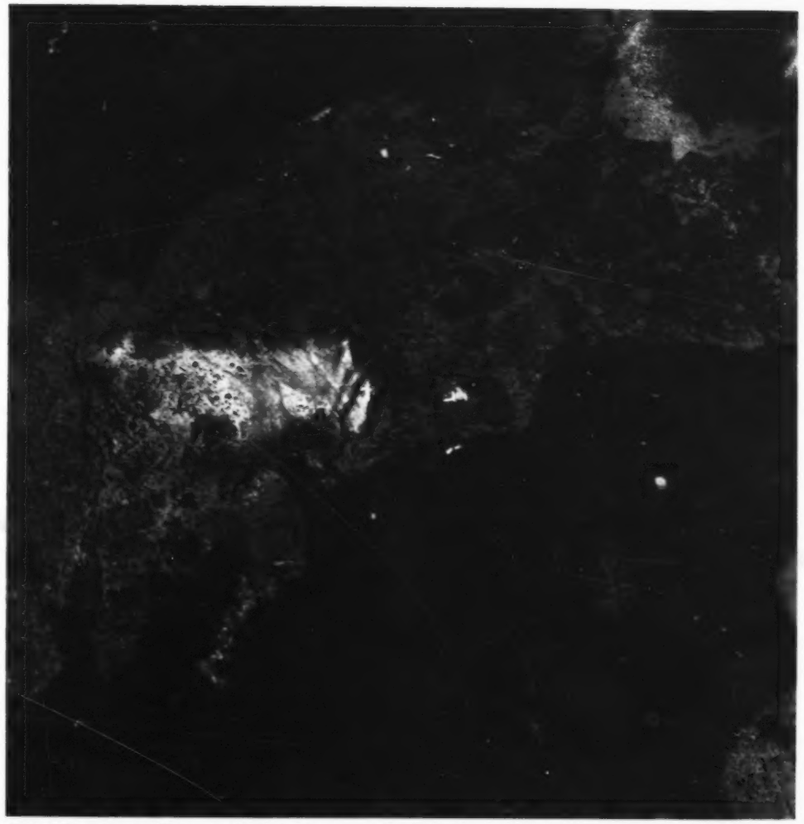
University of Michigan

Remote Sensing Projects Range from Michigan to India

Dario Rodriguez-Bejarano maps data on India as part of a "Fragile Environments" report for the U.S. State Department. His work will have a role in a United Nations Conference on Technology Transfer. "Landsat is used first to establish an overview," he said, "followed by other forms of remote sensing imagery for detail."

Susan Freyburger and Larry Sugarbaker analyze infrared imagery to map vegetation cover types from before and after the August 1976 fire in the Seney National Wildlife Refuge. The effects of the fire on vegetation change are being carefully assessed.

On a Summer afternoon, Research Assistant John Lyon examines a printout from the Department's computer terminal. He is studying the use of Landsat data for water and wetland inventory in Michigan.



Landsat imagery for 23 August 1976 clearly shows the dimensions of a major forest fire at Walsh Ditch in the Seney National Wildlife Refuge. This was the fire studied by Remote Sensing Program personnel to evaluate the impact on vegetation. Landsat's repetitive coverage and frequency of return make it useful in recording the effects of natural calamities such as fire, flood, and earthquake, as well as in conventional remote sensing applications.

Chase-Mogdis Incorporated

Private Consultants with Experience and Expertise in Remote Sensing

Phillip Chase and his associates at Chase-Mogdis serve private and public sector clients as consultants specializing in business management, energy, environment, and new technology areas. Landsat is a continuous supplier of data potentially useful in many of their assignments.

"As consultants, we start every assignment with these basic questions: What's the job? What's the area involved? What method will give desired results at the lowest cost? Sometimes Landsat is the choice with dramatic cost savings, sometimes not. Landsat is an exciting technology and can be very useful when applied with care. It is important to be realistic and not oversell what it can do. If a client is promised 95% results and only gets 75%, he's unhappy. That's bad for business. If this was a problem with Landsat, it has been corrected. Today Landsat information is excellent for large areas, and it mixes well with data from other sources."

Phillip E. Chase
Vice-President
Chase-Mogdis Incorporated
204 East Washington Street
Ann Arbor, Michigan 48104
313-995-3404

Phil Chase is a pioneer in the development and application of Landsat multispectral data. His involvement goes back to the start, when as an employee of the Bendix Aerospace Systems Division in the 1960's, he served as site engineer for construction of the ERTS ground station at NASA Goddard. He helped establish the software and equipment at Goddard for processing Landsat data.

Waiting for Detroit

When ERTS-1 (later called Landsat-1) was launched, Phil Chase was the principal investigator on two early experiments conducted by Bendix for NASA. He applied satellite data successfully to monitor strip mining effects and also initiated Landsat studies of lake eutrophication in Michigan. "I remember the tension," he says, "when we were waiting for the first Landsat imagery of Michigan and Detroit."

In time the imagery became available and so did the potential applications of Landsat. More recently Phil Chase worked with Landsat data preparing "208" reports for the Michigan Genesee-Lapeer-Shiawassee Region V Planning and Development Commission. Currently he is a consultant for General Electric on Landsat applications in the Great Lakes Basin area.

His accomplishments in remote sensing make Phil Chase an expert in the realistic employment of this technology. "We help clients find the best way to go," he says, "I expect Landsat more and more frequently to be part of the answer."

What would you do: 120,000 Square Miles for Land Cover Analysis?

The Great Lakes Basin Commission Turned to Landsat

A land cover analysis by watershed was needed and needed fast as a key part of the program to evaluate Great Lakes pollution from land use activities for the U.S. and Canadian International Joint Commission. The specific assignment from the U.S. Environmental Protection Agency Federal Region V was to inventory land cover and provide general classification data on watersheds in the U.S. Great Lakes Basin. This massive undertaking, essential for an up-to-date inventory of land use, was successfully completed in 1978 using Landsat.

In addition to that initial assignment, this Landsat project is now offering a wide range of productive spinoffs. For instance, the data broken down for 191 counties in eight states is supplied on request to county planners needing current land use information.

Human Interpretation Supplementing Computer Analysis

Thirty-four exceptionally clear Landsat images were obtained from the EROS Data Center in Sioux Falls, South Dakota for computer processing at the General Electric Image Processing and Analysis Center, Beltsville, Maryland. Ground truth was assembled from available sources such as surface observations, topographic maps, and aerial photography.

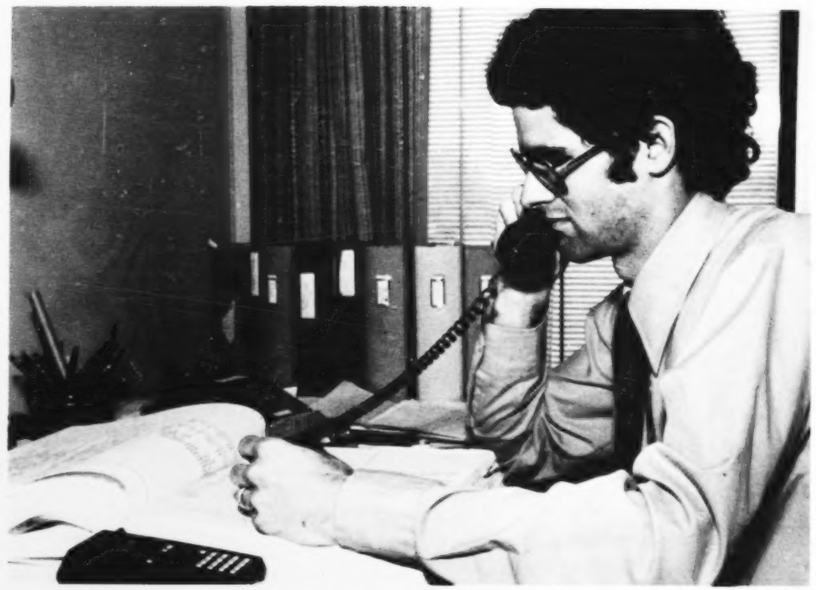
Tom Wescott, Earth and Resources Engineer, in charge of the effort at General Electric, calls the project, "Some of the best work ever done with Landsat." He says all those involved are "super-pleased with the results." During the project, careful human interpretation was used in conjunction with computer operations. "Our tape analysts used spatial pattern recognition," reported Mr. Wescott, "and the human interpreter is sharper at this than the computer."

This Landsat image for Michigan has a geographic overlay to facilitate use. The ability to match Landsat and geographic maps with great exactness was an important advancement in this project. Heavy lines will delineate the 72 major river basins covered. Lighter lines show counties and townships. These maps are useful supplements to the digital data.

Thirty-four Landsat scenes were used to prepare this mosaic providing a synoptic view of the U.S. Great Lakes Basin.

"Landsat was the only way to go on this project because of the area involved and the short time allotted. Funds also were a factor. Using aerial photography would have cost hundreds of thousands of dollars. The Landsat cost was less than a dollar per 500 hectares. Landsat proved to be a bargain. It gave us a good, functioning data base at a very reasonable price. We knew it was something of a gamble to use Landsat after an earlier study proved insufficient, because the state-of-the-art then wasn't far enough along. But we hoped to learn from past experience and to benefit from progress made in programming and data handling of satellite imagery. Landsat did extremely well. This project should establish its excellence and practicality for large areas. People were gullible about the pretty pictures before. They were oversold. I think we're beyond that now. Instead of trying to pick out our own house, we use Landsat for what it's good at, general classes such as grasslands, forests, wetlands. Landsat-3 promises even more. I hope the Great Lakes Basin Project turns things around for Landsat. I know here it changed the minds of some people who had been skeptical."

Timothy J. Monteith
Water Resources Engineer
Great Lakes Basin Commission
3475 Plymouth Road
P.O. Box 999
Ann Arbor, Michigan 48106
313-668-2300



Computer printouts giving detailed land cover tabulation figures for nine classes of information are practical, highly useful information sources available from the Great Lakes Basin Commission to groups responsible for regional or land planning in the U.S. Great Lakes Drainage Area.

Entering Tim Monteith's office, you quickly notice the small cabinet of computer tapes behind his desk. You learn the tapes contain land cover data on 120,000 square miles, that over seventeen miles of magnetic tape were processed to create them.

The outcome of the Great Lakes Basin Commission Project shows a marked improvement over earlier projects. An inventory of land cover classes in the watersheds of the U.S. Great Lakes Basin was achieved at a lower cost and with better results than were considered possible at the start. "We studied the matter thoroughly," says Tim Monteith, "Landsat was obviously the best solution. How else could you analyze 120,000 square miles for $50,000?"

Michigan Transportation Planning

An Opportunity for Landsat and Computerized Data

Choosing the Corridor

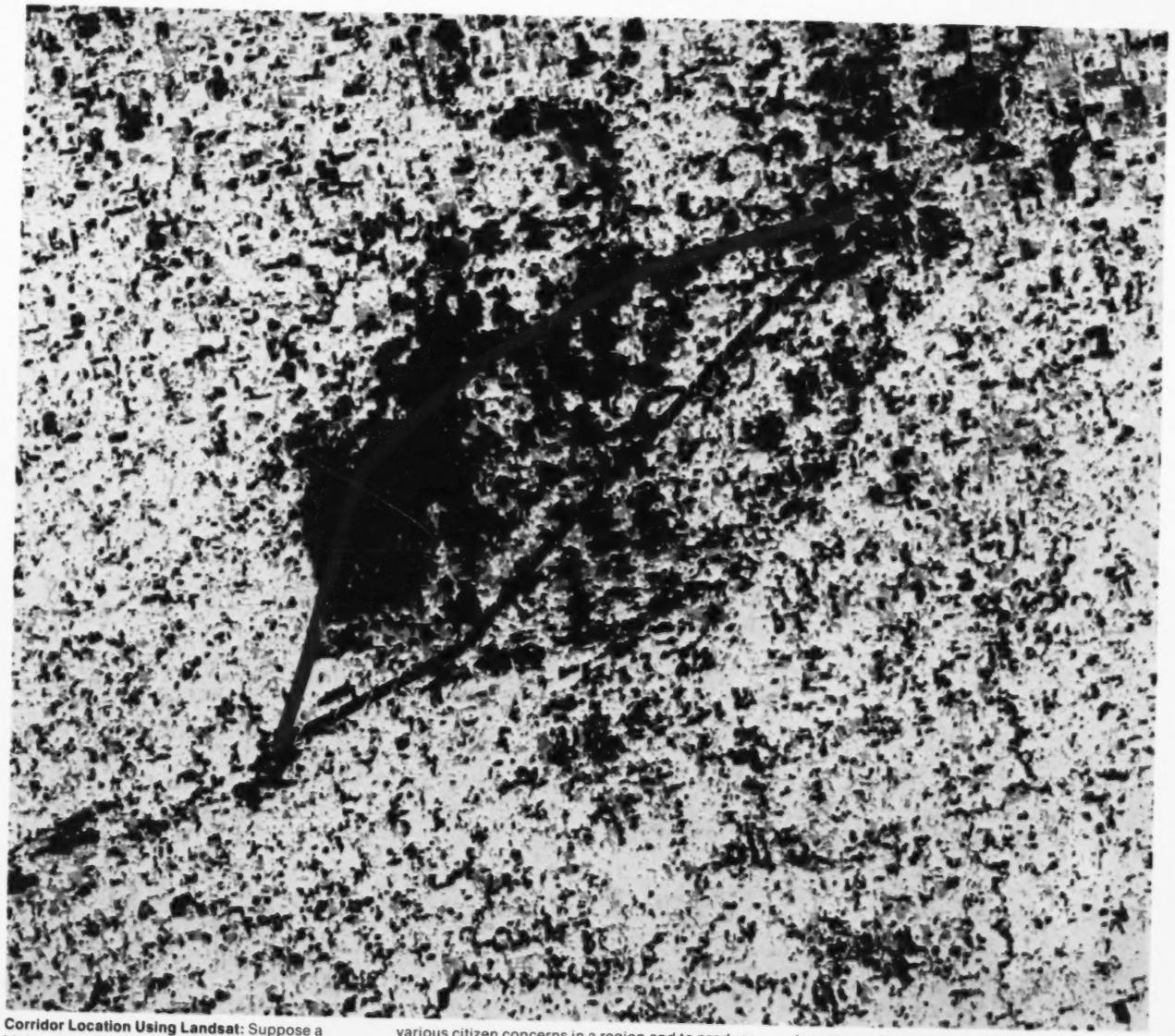
Many people today view highways as enemies of the environment. This is true because highway systems have been built as separate engineering projects answering only transportation needs. Ideally each highway should be planned as part of the total environment. Then road construction becomes a positive force helping men live harmoniously with nature and each other.

Before any highway is constructed, many issues—economic, social, environmental—must be identified and appropriately weighed to determine the best route. In our society different interest groups weigh issues differently. Here logic and mathematics can be used to allow more active citizen participation in the planning process when determining optimal corridors.

How Landsat Helps

The Michigan Department of State Highways and Transportation addresses these challenges by using mathematics and computer technology. Necessary land use information, such as location of lakes, woodlands, wetlands, and agricultural areas, is available through utilization of Landsat technology. This information covers large areas, can be economically updated, and offers sufficient detail for regional and statewide planning. A mathematical model, utilizing Landsat data, has been programmed for a high speed digital computer. A cathode-ray tube is employed to enter the weights for different land uses and to display land use maps and resulting optimal corridors.

The important features of the model are flexibility in evaluating many different points of view, precision in choosing the corridor, and the ability to interact with users. This process has been applied to several highway projects in Michigan on both a regional and statewide scale.



Corridor Location Using Landsat: Suppose a highway realignment is needed between two cities separated by prime agricultural land, wetlands, and barren vacant areas. The Michigan process utilizing Landsat allows planners to examine pictorially various citizen concerns in a region and to produce a land use map with a corridor overlay—as suggested on this Landsat image—based on the weight given each concern. If preservation of wetlands is important, the land use map would have a corridor drawn to avoid wetland areas. If barren vacant land is a low concern, the corridor drawn would make maximum use of available vacant land.

"We think of Landsat as a source of information that finally made statewide and regional transportation impact analysis a practical possibility. We are truly excited about the potential of this process and the role Landsat will play, because we will be able to increase our ability dramatically to involve citizens and other agencies directly in the transportation planning process. This methodology will also allow increased utilization of departmental staff by transferring them from more tedious data collection processes to transportation planning analysis. There is potential as well for multi-departmental application, because many agencies are interested in land use information and the impact transportation plans have on their daily planning functions.

Finally, the process has been designed to make it compatible with existing efforts in the department to utilize color infrared information for detailed project planning."

Richard E. Esch
Michigan Department of State Highways & Transportation
Bureau of Transportation Planning
P.O. Box 30050
Lansing, Michigan 48909
517-373-2663

Because Landsat data are not used for an isolated project but integrated into a larger statewide transportation modeling system, there is need for personnel with a variety of skills. George Liu has an extensive mathematical background and is keenly interested in land use planning. Terry Gotts contributes his expertise in computer analysis and data base development. Tom Bordeaux's experience in dealing with the daily problems of transportation planning ensures that Landsat is being used to solve real life problems.

Michigan State University Remote Sensing Project

Landsat Applications with Emphasis on the Practical

Getting the Job Done

Visit the Remote Sensing Project facility in the Urban Planning and Landscape Architecture Building on the MSU campus for professional remote sensing assistance in connection with land or water resources. Started in 1972, the Remote Sensing Project was initially funded by NASA. The Project has grown rapidly and now obtains a substantial part of its funds by performing assignments for a wide range of clients in addition to NASA, including Michigan's Department of Natural Resources, the U.S. Department of Agriculture, regional planning commissions, and private business.

Director William R. Enslin, Associate Director Stephen E. Tilmann, with a dedicated group of research specialists, assistants, and students, apply every type of remote sensing currently available.

Touring the Project, you may encounter Steve Tilmann at the Color Additive Viewer adding color to individual Landsat bands to highlight features for a group of Dominican Republic technicians studying Landsat interpretation. Full-time Specialist Dennis Hudson may be absorbed with Landsat imagery at the Zoom Transfer Scope to identify wood resources for an energy project in West Central Michigan. Research Assistant Richard Hill-Rowley perhaps is writing a report to extend the Project's original work in merging Landsat data and digitized photographic data to create map products such as the Michigan GLS Region V composite. Bill Enslin may be occupied identifying wild areas for Michigan DNR, studying data on sand mining activities, discussing the wood energy assignment with representatives from the consortium backing the effort, or a dozen other possibilities.

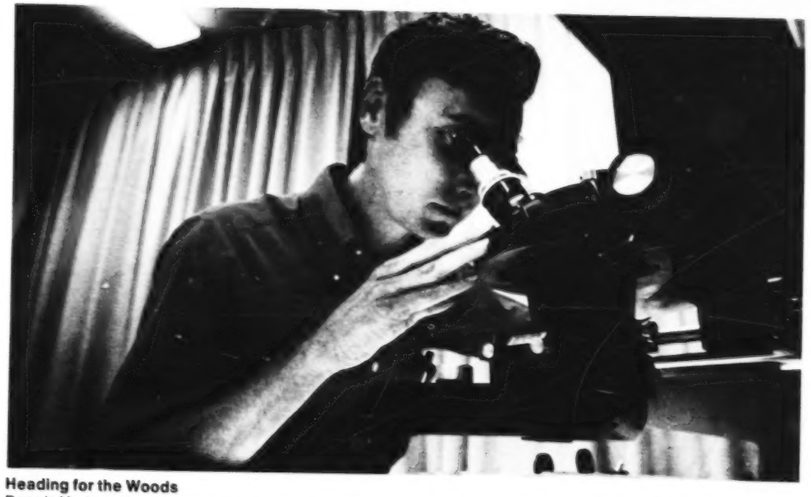
It's a busy place. To serve the needs of government and business in Michigan as well as other parts of the world, the Project draws on the skills and resources of nine university departments at MSU. The ably staffed and well-stocked laboratory, including teletype terminals connected with MSU's main computer system, is designed to apply remote sensing technology, Landsat included, to solve contemporary problems.

Workshops, Consultation, Publications

To learn about Landsat or other remote sensing techniques, a Project Workshop is a good choice. Consultation on remote sensing applications is available too. Project publications are also helpful, such as the "Guide to Aerial Imagery of Michigan" by Bill Enslin and Richard Hill-Rowley. This 1977 Research Report, prepared under a NASA grant, contains an excellent Landsat section, covering the subject thoroughly with easy-to-follow details on ordering Landsat products.

"We use Landsat extensively, especially at the start of projects such as identifying wild areas in Lower Michigan or surveying wood resources in West Central Michigan. Landsat is valuable in narrowing down the area, helping us focus our efforts with more precision. In the forest project, we analyze Landsat data to locate forest acreage in the study areas. After the initial inventory, we'll determine biomass tonnage using Landsat, aerial photography, and ground truth determined on-site. Landsat is the vital first step in a multi-step process. Our job includes determining the best remote sensing approach for each assignment, and being able to apply it effectively. That's why in remote sensing we don't specialize in any one application. We have to specialize in all of them as much as possible. Among Project activities are workshops using Landsat and other remote sensing tools. I remember one workshop compliment especially. They liked it because we tried to show them what can be done now, not what we hope can be done in the future. in GLS Region V, the Dominican Republic, and other assignments, I think we've proved useful things can be done with Landsat right now."

William R. Enslin
Remote Sensing Project
Michigan State University
201 UPLA Building
East Lansing, Michigan 48824
517-353-7195



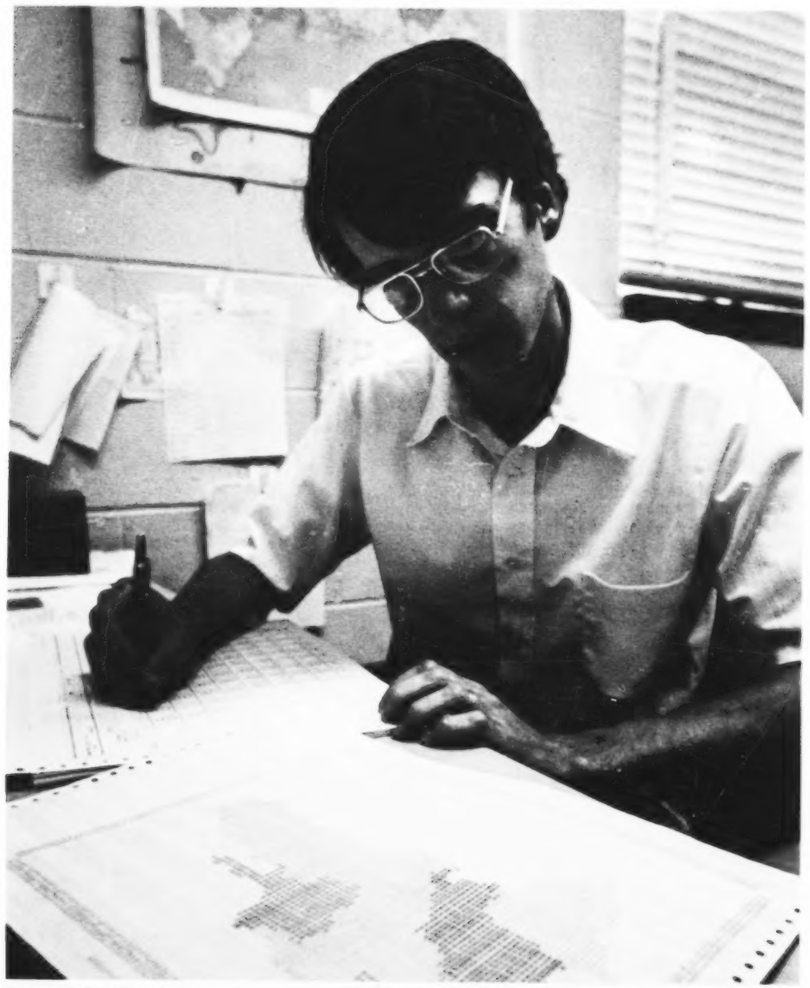
Heading for the Woods
Dennis Hudson first studies imagery, then he puts on his hiking shoes and collects on-site data. He is applying remote sensing technology to help Michigan industries learn more about wood biomass and the prospects for using wood as an energy source in a state over 50% forested.

Ground Sampling for Wood Biomass
A sample forest cover type is harvested and then full-tree-chipped by a Morbark total tree chipharvester. Tonnage figures derived from weighing the green chips, when combined with data on forest acreage from Landsat, provide an estimate of standing biomass as an energy source.

◆ Landsat images of West Central Michigan such as this scene provide forest acreage data.

Michigan State University

At the Remote Sensing Project, You're Not Tied to a Desk



The Need for Many Skills
A modern remote sensing specialist must wear more hats than one. His work may require him to be a computer expert, image interpreter, photographer, geographer, statistician, and even an explorer in the mountains of the Dominican Republic. Talk to Steve Tilmann at the Remote Sensing Project. He wears these hats and more. Steve Tilmann, who conceived the idea of merging Landsat and aerial photography data, here analyzes computer data on the Dominican Republic project. Landsat is being used at MSU to determine major land cover categories for the country. Training local people in the use and interpretation of data is another Project responsibility. Steve Tilmann went to the Dominican Republic to establish ground truth for visual interpretation of Landsat imagery.

Salonika, Greece to East Lansing, Michigan
Michael Karteris, a photointerpreter from Aristotle University in Salonika, Greece, applies skills developed in the Remote Sensing Project as he superimposes and enlarges images.

Getting Off the Ground
To produce training sets for Landsat interpretation, photographs are often necessary from aircraft. Here Richard Hill-Rowley holds the camera for a vertical shot while Bill Enslin fires the camera.

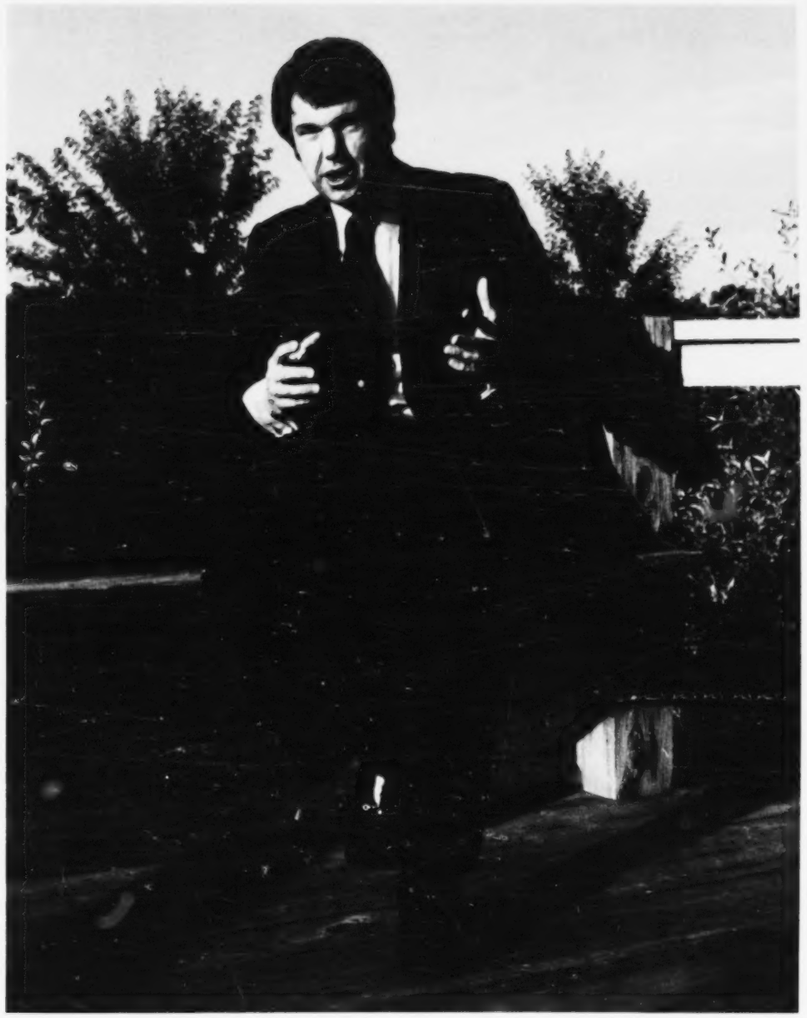
MERRA and Landsat

A Michigan Partnership for Progress

The days when major scientific and technical research breakthroughs come from the efforts of a Benjamin Franklin, a Thomas Edison, or an Alexander Graham Bell working alone and stubbornly asking questions of nature are not gone and never will be. But today much more than genius working alone is often required. Modern research and the successful application of our complex technologies cross many professional lines and scientific disciplines—just as Landsat traverses national boundaries in its daily orbits. Effective use of technology and research for maximum progress, service, and the benefit of citizens now requires dedicated and tireless coordination efforts. In Michigan, those efforts are among the leading responsibilities and concerns of MERRA. Fulfilling its broad responsibilities, MERRA acknowledges the growing contribution of Landsat.

"MERRA stands for the Michigan Energy and Resource Research Association, a partnership of Michigan state government, industry, and universities. Our job is to coordinate research activities beneficial to the state of Michigan. Landsat is an important part of our plans. It has already done significant work for Michigan and has tremendous further contributions to make. Because the use of Landsat affects so many aspects of Michigan work and life, we have to be involved. Working with member organizations on various projects, I've increasingly noticed the application of Landsat in Michigan resource management. Recently, for instance, MERRA has cooperated with four Michigan companies studying the feasibility of using wood to help supply Michigan's energy needs. Our goal is a new industry growing and consuming wood biomass to produce energy. This makes good sense in our state with a wealth of forest resources. How is Landsat involved? The Michigan State University Remote Sensing Project in assessing timber supplies is relying heavily on Landsat. This is just one example of many. There is no doubt Landsat will be a key information and data source from now on. We recommend Landsat whenever it serves a practical need. In the resource and energy fields, that happens more and more often."

Todd Anuskiewicz
Research Director
Michigan Energy and Resource Research Association
328 Executive Plaza
1200 Sixth Street
Detroit, Michigan 48226
313-964-5030



Landsat—
Linking Past, Present, Future

"With the expansion of the world's mental horizons may come one of the greatest outbursts of creative activity ever known."

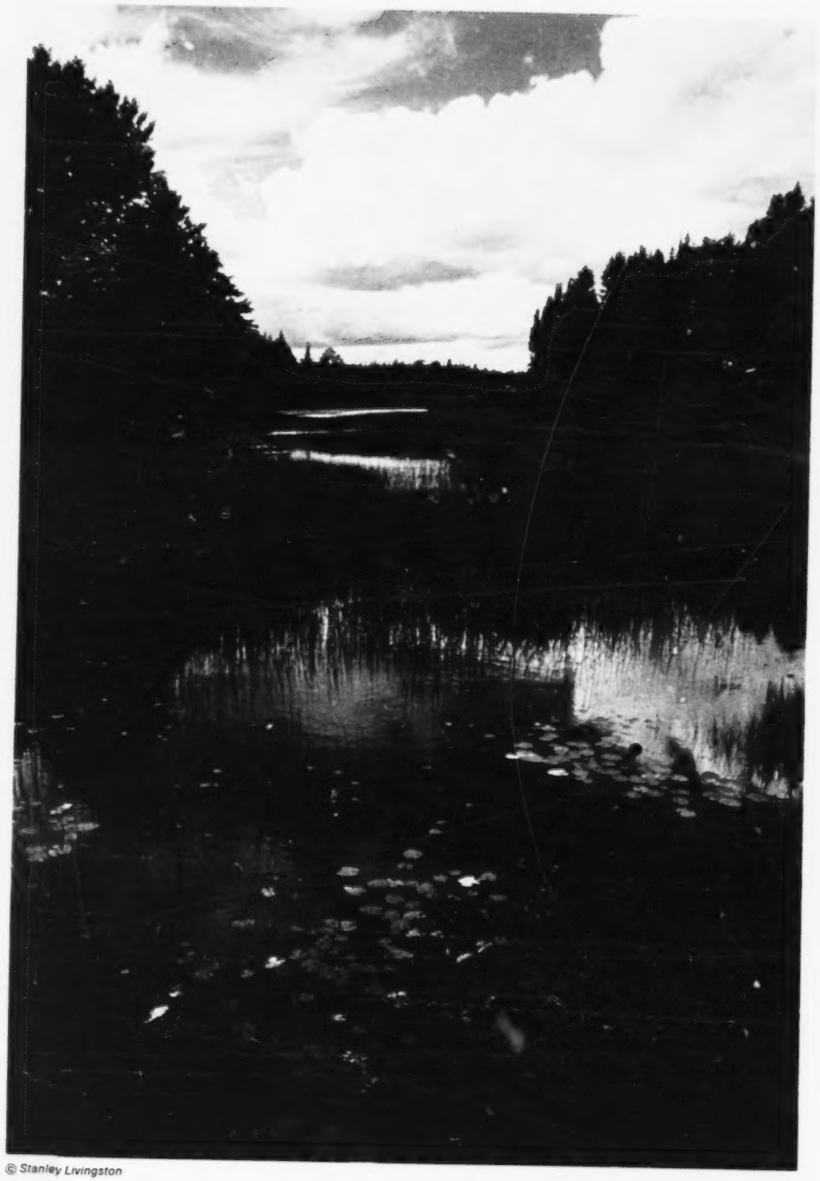
Arthur C. Clarke, 1946

During its brief history, Landsat has expanded all our horizons, both mental and physical. It has expanded the horizons of the past as well as the future.

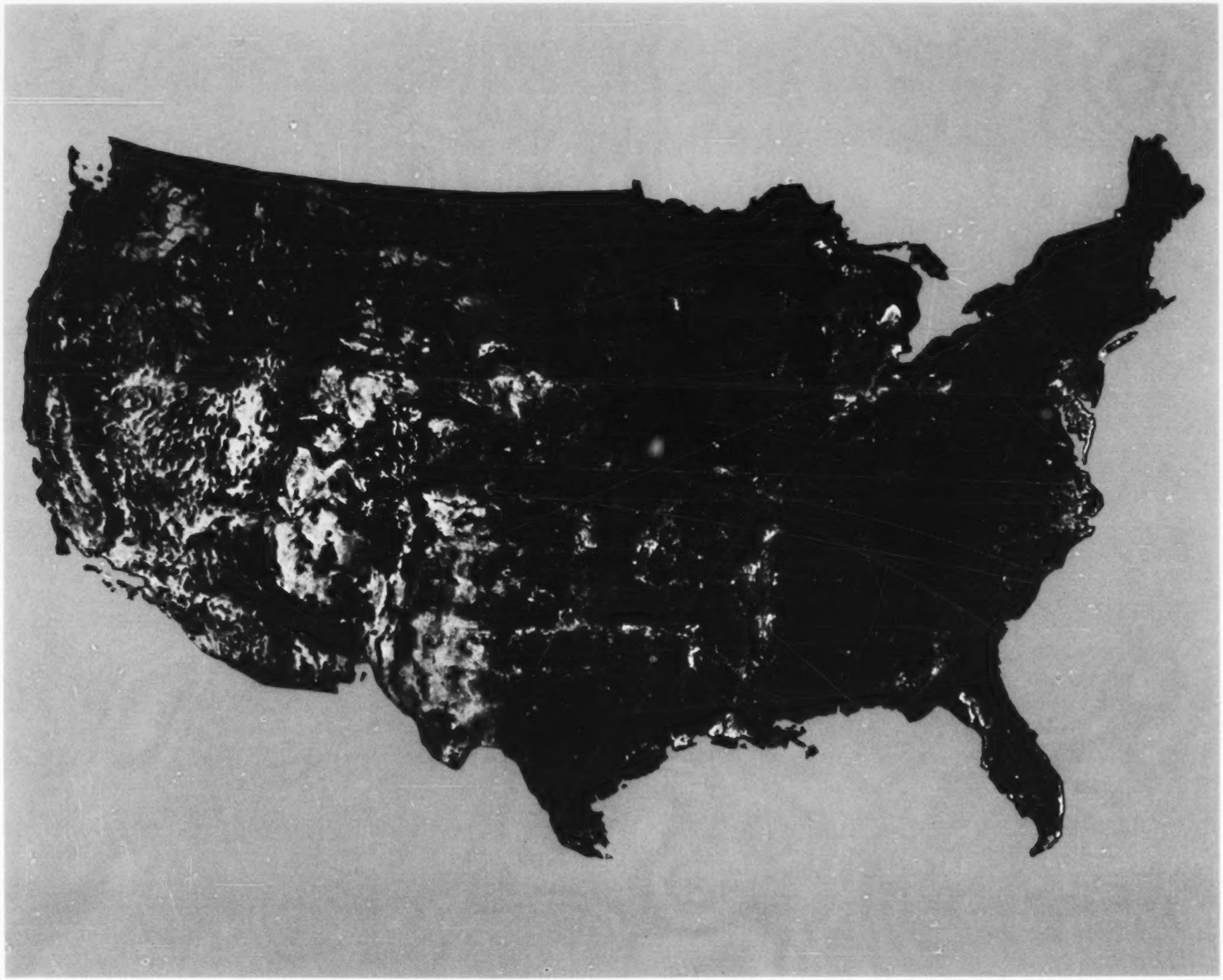
At Chaco Canyon National Monument in New Mexico, Landsat remote sensing and computer analysis gave archeologists studying ancient Indian civilizations a vital clue to an elaborate road system developed nearly a thousand years ago. This discovery, through modern space technology, is helping unveil our past.

Landsat makes equally significant disclosures about the present and future. Today Landsat in Michigan is a support for resource management, modern highway planning, mineral prospecting, water quality surveillance, environmental monitoring, and related activities important to every citizen. Users of Landsat data in Michigan agree that Landsat will have an expanding role in future environmental and resource concerns.

There is growing awareness that satellite imagery is a promising, long-term source of practical intelligence about the earth. Landsat is discovering the earth for us in new ways. Why don't you discover Landsat? Why don't you begin learning and applying the benefits of this unique information provider now?



© Stanley Livingston



NASA

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771